



# Experimental Research on Combustion Characteristics of Air-supported Membrane Materials

ZHANG Yuan-yuan<sup>a,b</sup>, ZHU Guo-qing<sup>a,b</sup>, YANG Hui<sup>a,b,\*</sup>

<sup>a</sup>Faculty of safety engineering, China University of Mining and Technology, Xuzhou 221116, China

<sup>b</sup>Fire research institute, China University of Mining and Technology, Xuzhou 221116, China

## Abstract

Based on the combustion experiment of combustion characteristics of air-supported membrane materials the fire dynamic phenomenon at different heights was studied, and the combustion critical temperature of the membrane materials was obtained, shrinkage, tension and thinning appeared on the surface of the membrane materials after the material was heated. When the temperature reached the critical temperature, the membrane materials began burning, appearing a hole with a cloud of thick black smoke. In the course of the experiment droplet phenomenon didn't appear. Temperature data was collected by using the data collecting system Agilent 34970A. Results show that critical temperature of the air-supported membrane material when the material begin pyrolysis and burn is about 365.5 °C to 437.6 °C.

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Selection and peer-review under responsibility of School of Engineering of Sun Yat-sen University

**Keywords:** air-supported membranes; combustion experiment critical temperature

## 1. Introduction

In recent years, there has been some a new membrane structure or gas membrane buildings in china and abroad, whose structures and buildings are as a whole. Membrane structure is a major new architecture structure form in large span space structure. Quite different from traditional structures, membrane structures use the fabric with excellent performance as materials, supporting the membrane surface by intra membrane air pressure, or flexible cables and the rigid support structures, which tighten up surfaces by curved inner surface force to form structural systems covering a large span of space with certain stiffness and tension, widely used in sports, entertainment, business and industry.<sup>[1-2]</sup> The study and development focus of air-supported membranes is the improvement of membrane surface technology, to possess good membrane-forming ability, thermal stability, acid and alkaline resistance, microbiological resistance and oxidative resistance. At present the advanced air membrane material mainly has PVDF membrane of Kynar<sup>[3]</sup> Company and tubular membrane of POREX<sup>[4]</sup> Company. Each country is studying the application of nanotechnology in the membrane material research and development.<sup>[5]</sup> For now, the study at home and abroad is primarily on membrane material and membrane process, lack of combustion characteristics of air-supported membrane material. But the main feature of air-supported membrane structure buildings is the large building volume. Once fire accidents happened, it will spread quickly and have difficulty in evacuation and fighting fire disasters. Therefore, it's necessary to research on combustion characteristics of air-supported membrane material. Based on experiment on air-supported membrane material, this article obtains flame temperature in the combustion

Process of membrane material: and critical temperature of decomposition and combustion, by observing fire dynamics phenomenon of membrane material.

\*Corresponding author. Tel.: +86-15262144173.

E-mail address: [zhangyuan yuan1215@126.com](mailto:zhangyuan yuan1215@126.com)

## 2. Experimental design on combustion characteristics of air-supported membrane material

### 2.1. Air-supported membrane material properties

The structure is inflatable through the pressure control system to the building interior, maintaining a certain differential pressure between indoor and outdoor. By buoyancy force, membrane produces a certain pretension which ensures the stiffness of the system and makes the membrane surfaces expands gradually into stable condition. Set automatic air conditioning system indoor to modulate the interior pressure constantly in order to adapt to changes in the external load.<sup>[6]</sup> Indoor and outdoor pressure difference is generally about 250 Pa equivalent of the atmosphere differential pressure of the residential building from first floor to ninth floor. Because the pressure of the air-supported membrane is small, ordinary people do not feel it physically and it is safe and feasible, its span of up to around 200 m.<sup>[7]</sup>

The air-supported membrane material used in the experiment is a monolayer of moderate intensity PVC membrane, which is white, and a kind of composite materials with high strength, flame retardant, durable, self-cleaning performance, etc. Its flame retardant and high temperature resistance performance has reached the B1 Level standard of 《GB8624—1997》 which is called Building Materials Flammability Classification Method. The thickness is only 0.61 mm, but its tensile strength is equivalent to half of the steel. The elastic modulus of membrane is very small and it is conducive to the formation of complex surface modeling. PVC membrane material is a kind of composite materials which is formed by a substrate coated with PVC or polyvinyl chloride resin.<sup>[8]</sup> PVC membrane material has the advantage of easy processing, low-cost, coloring, recyclable, etc. And because of the performance of flame resistance, it will not cause the expansion and spread of fire. The experiment indicates that PVC membrane material has superiority from the perspective of the actual response of membrane structures under fire.

### 2.2. Combustion experiment design

July 2012, several air-supported membrane material combustion experiments have been done in the Fire Engineering Laboratory of China University of Mining and Technology, which are selected five groups of them into analysis. The ambient temperature during the experiment is 30 °C. Experimental groups are shown in Table1.

Table1. The design of experimental classifications

Experimental groups	Test height (cm)	Specimen size of air-supported membrane (cm×cm)	Stainless steel plate sectional area (cm <sup>2</sup> )
1	50	20×20	153.86
2	45	20×20	
3	40	20×20	
4	35	20×20	
5	35	50×50	

The experimental equipments used in the experiment are shown in Table 2. Experimental apparatus includes mainly experimental bracket, image collection system and data acquisition system. Use K-type thermocouple to determine the temperature of the air-supported membrane at the center position and Agilent 34970A to collect temperature data. Besides, camera the combustion process of the air-supported membrane. Experimental apparatus is shown in Fig. 1.

Table 2. The list of experimental equipment

Number	Equipment Name	Number	Equipment Name
1	Agilent 34970A data collector	8	Experimental bracket
2	Electronic scales	9	Forceps
3	SCC-B230P/B2003P camera	10	Air-supported membranes
4	K-type thermocouple	11	Aluminum foil
5	Diesel fuel	12	Ignition
6	stainless steel plate	13	Iron wire

7

Scale

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Asbestos board

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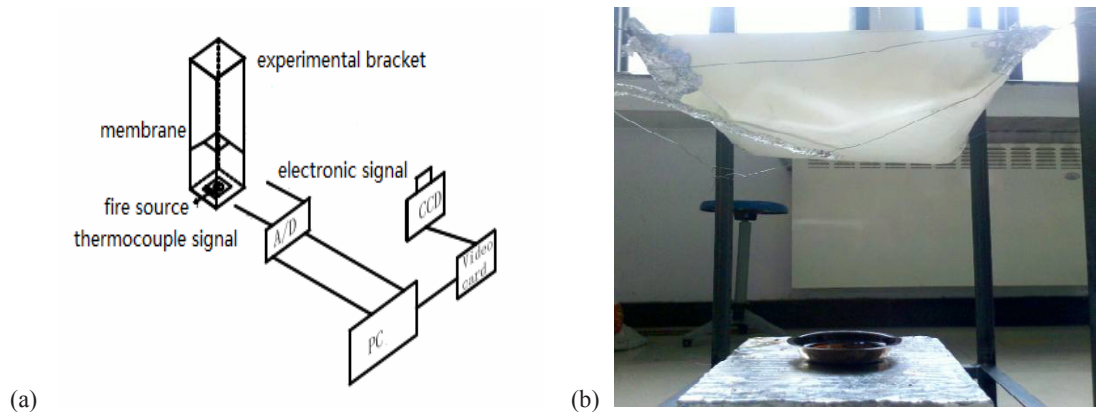


Fig. 1. (a) The schematic diagram of experiment equipment system (b) Assembled view of experiment equipment

### 3. Experiment phenomena and analysis

#### 3.1. Small-size experiment (20 cm × 20 cm)

A heating experiment was done for the membrane sample of 20 cm × 20 cm, at different heights of 50 cm, 45 cm, 40 cm, 35 cm.

The experiment results indicated: when the flame is not in direct contact with the air-supported membrane and vertical height of the membrane material from the ignition source is 50 cm, and the membrane produces a tiny contraction under the action of gas produced by the diesel combustion; the membrane produces a certain extent contraction under the action of smoke plume at the height of 45 cm, but there is no hole during the whole experiment; at the height of 40 cm, the membrane produces a greater contraction and it begins to bulge in the middle of the membrane, but there is no hole yet; at the height of 35 cm, the membrane develops into a serious tension, then gradually levels off and a small bubble appears in the middle of the membrane, then it tears into a hole. Four groups of heating experiment phenomena are shown in Fig. 2. The burning hole is circled with the red circle.

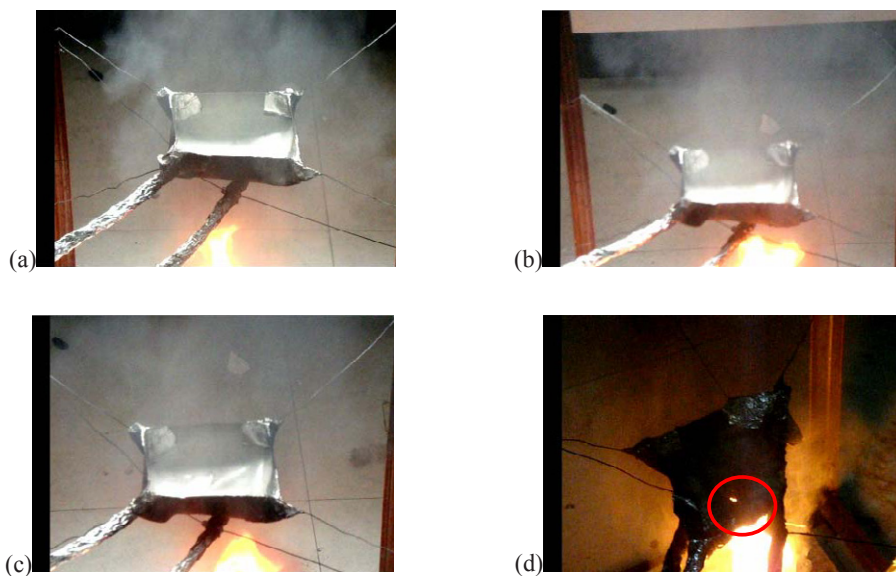


Fig. 2.(a) Experimental phenomena of small-size membranes in 50 cm (b) Experimental phenomena of small-size membranes in 45 cm (c) Experimental phenomena of small-size membranes in 40 cm (d) Experimental phenomena of small-size membranes in 35 cm

### 3.2. Medium-size experiment (50 cm × 50 cm)

In order to further verify heating situation of the membrane sample, heating experiment was done for the membrane sample of 50 cm×50 cm, at the height of 35 cm.

The experiment results indicated: under the action of fire plume, the pyrolysis of the membrane happens gradually, then the membrane experiences compression and tension, and then it tears into a hole. Heating experiment phenomena for the membrane are shown in Fig. 3. The burning hole is circled with the red circle.



Fig. 3. Experimental phenomena of medium-size membranes in 35 cm

### 3.3. Experiment phenomena and analysis

By observing heating experiment phenomena for small-size experiment and medium-size membrane, the characteristics and laws of burning air-supported membrane can be concluded as follows:

- Smoke plume generated by the flame has a little influence on the air-supported membrane, when the flame is not in direct contact with the air-supported membrane. During the experiment, the membrane appears a certain contraction deformation, but not the hole.
- The pyrolysis of the membrane happens, then the membrane has a shrinkage deformation, then tears into a burning hole, and accompanied by thick black smoke. After the membrane is burn though, there is a open hole corresponding to the size of surface that the fire contacts with the membrane. Heat, smoke and gases discharges automatically, and the size of the open hole remains unchanged until the flame is extinguished.
- During the experiment, no droplets are not formed which can become secondary ignition sources.

## 4. Air-supported membrane critical temperature experimental data analysis

Under the action of the fire, the pyrolysis of the membrane happens gradually, then the membrane experiences compression and tension. The membrane produces a burning hole when the temperature reaches the critical temperature. The critical temperature is regarded as the criterion for the membrane to decide whether it is destroyed in the fire. In order to research the critical temperature under the action of fire, the data of experiment 3、4、5 is analyzed, and the experiments are more ideal and comparative.

### 4.1. Experimental data analysis

Select the experimental data whose membrane sample size is 20 cm×20 cm and vertical height of the membrane material from the ignition source is 40 cm. we make a statistical analysis of the temperature data collected. The article concludes that the maximum temperature of the surface of the membrane during combustion is 365.5 °C. There is no hole in the membrane. The temperature change during the experiment is shown in Fig. 4.

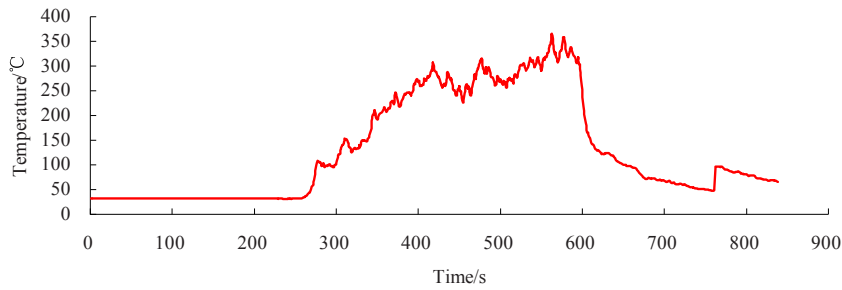


Fig. 4. Temperature of 20×20 membranes surface in 40cm

Select the experimental data whose membrane sample size is 20 cm×20 cm and vertical height of the membrane material from the ignition source is 35 cm. Through analyzing the temperature data collected, we can conclude that, in the combustion process, when the highest surface temperature reaches 468 °C, holes will appear on the surface of the membrane. The temperature change during the experiment is shown in Fig. 5.

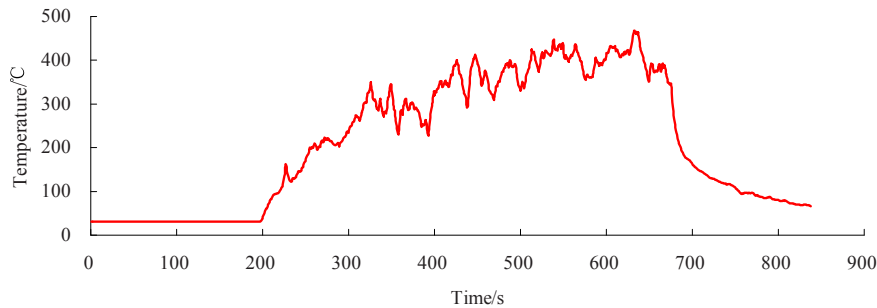


Fig. 5. Temperature of 20×20 membranes surface in 35 cm

Select the experimental data whose membrane sample size is 50 cm×50 cm and vertical height of the membrane material from the ignition source is 35 cm. Through analyzing the temperature data collected, we can conclude that, in the combustion process, when the highest surface temperature reaches 437.6 °C, holes will appear on the surface of the membrane. The temperature change during the experiment is shown in Fig. 6.

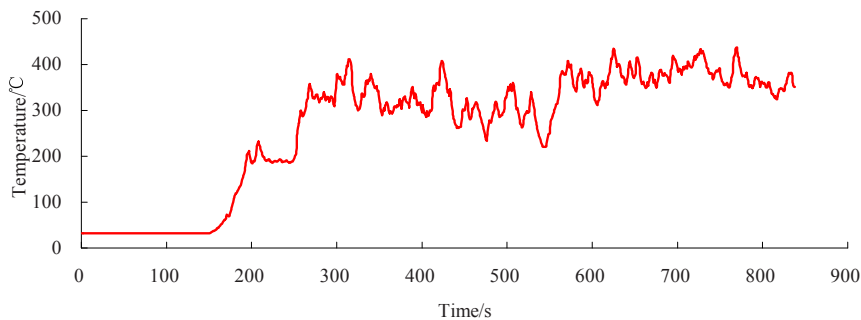


Fig. 6. Temperature of 50×50 membranes surface in 35 cm

#### 4.2. Summary of the results of the experimental data

Summary of the above three groups of experimental data analysis, the results as shown in Table3. From the table, we can get the critical temperature of air-supported membrane cracking and burning a hole is about 365.5 °C ~437.6 °C.

Table3. Summary of the results of the experimental data

Height (cm)	Size of air-supported membrane(cm×cm)	Experimental results	Maximum temperature(°C)
40	20×20	Not hold	365.5
35	20×20	hold	468
35	50×50	hold	437.6

#### 5. Conclusion

Through the analysis of experimental photographs, video and data, we can get the properties of air-supported membrane combustion following:

- When the flame is not in direct contact with the air-supported membrane, the membrane will not burn a hole.
- When the flame is in direct contact with the air-supported membrane, the membrane will pyrolyze rapidly, followed by burning a hole. The size of the open hole will not change until the flame goes out.
- By heating on the bottom of the membrane, tense and shrink the membrane surface slowly. After the membrane surface temperature reaches the critical temperature, a hole begins to appear on the surface, accompanied by thick smoke. During the experiment, no droplets are not formed which can become secondary ignition sources.
- In the fire environment by the direct effect of the flame, we can get the critical temperature of air-supported membrane cracking and burning a hole is about 365.5 °C ~437.6 °C.

The above conclusions apply only to the small size of the experimental study and have a guiding role in architectural fire safety design and protecting the safe use of such building. Some other combustion characteristics of materials as well as the air-supported membrane architectural performance-base design still subject to further investigation.

#### Acknowledgements

Thank my tutor Zhu Guo-qing's guidance and useful discussions and my schoolmate Yin Fei, Liu Shu-jin and Han Ru-shi's writing assistance. The work was supported by Science and Technology program of Housing and Urban-Rural Development Ministry (2011-K1-53) and it was also supported by the fire laboratory of China University of mining and technology.

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